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Stack Test Results at Phelps-Dodge Corporation Ajo, Arizona. Volume III

Acurex Corp, Mountain View, Calif Aerotherm Div

Prepared for

Environmental Protection Agency, San Francisco, Calif Region IX

Mar 77

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Aerotherm Project 7211

STACK TEST RESULTS AT PHELPS-DODGE CORPORATION, AJO, ARIZONA

Volume III

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485 Clyde Avenue
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March 1977

AEROTHERM FINAL REPORT 76-231

Prepared for

EPA Task Officer – L. Bowerman

Enforcement Division
Environmental Protection Agency, Region IX
100 California Street
San Francisco, California 94111

Contract 68-01-3158
Task 12

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15. Supplementary Notes

16. Abstracts

In July 1976 at the request of EPA, Region IX, Enforcement Division, the Aerotherm Division of the Acurex Corporation conducted a series of air pollutant mass emissions tests at the new Cornelia Branch copper smelte smelter of the Phelps Dodge Corporation located in Ajo, Arizona. The tests were performed simultaneously at three locations: 1)the main stack, 2)the reverberatory furnace duct and 3)the converter side sulfuric acid plant tail gas duct. Tests for particulate matter (Method 5), sulfur dioxide and sulfuric acid (Method 8) were conducted at each location using a combined sampling train. In addition tests for "condensable particulate matter" were conducted at the main stack and the reverberatory furnace duct using the combined Method 5 and 8 sampling train with an instack filter added.

17. Key Words and Document Analysis. 17a. Descriptors

Particulate Matter
Air Pollution
Copper Smelters
Sulfur Dioxide
Sulfuric Acid
Stack Sampling
Air Measurement
Ajo, Arizona

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

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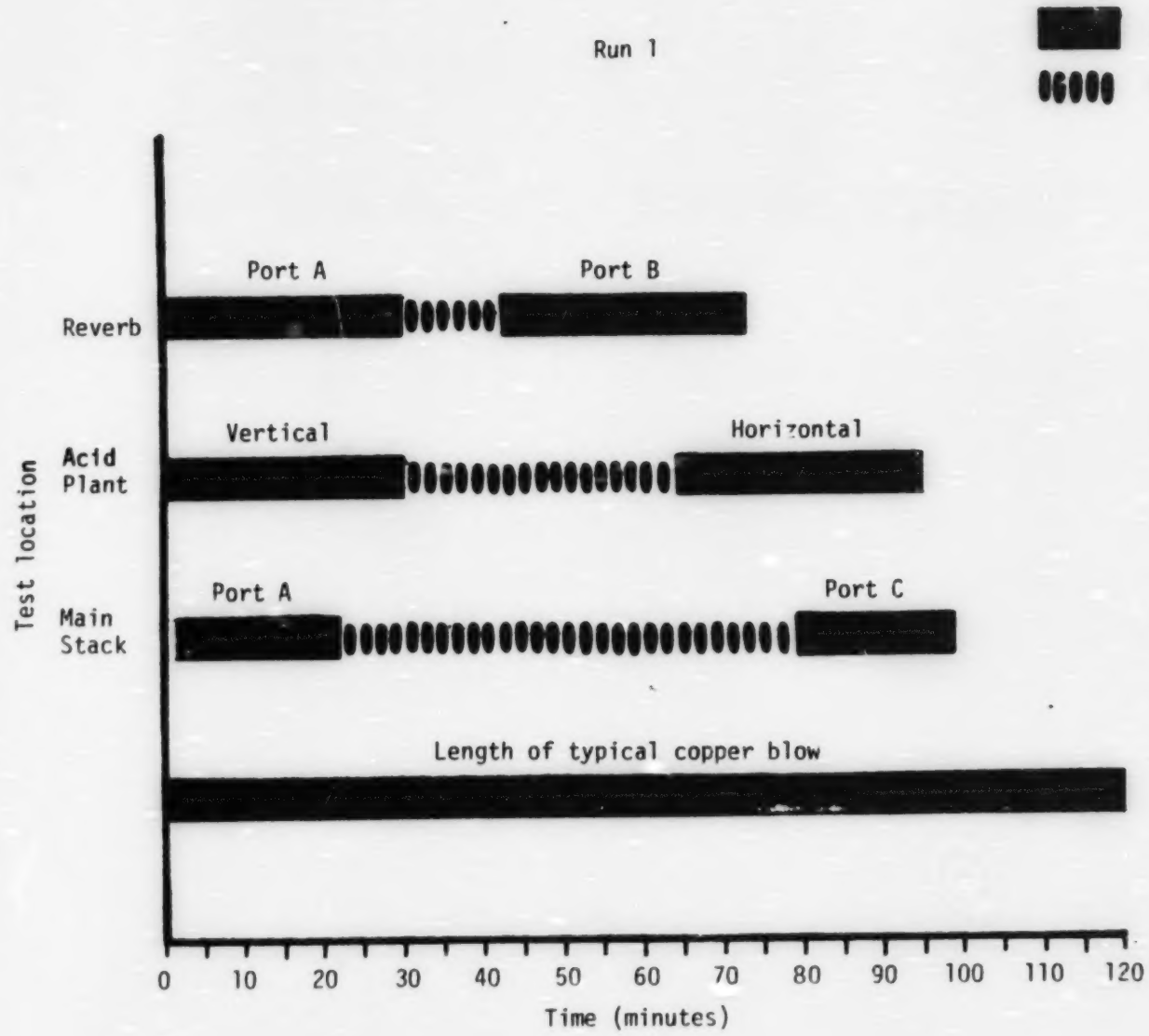
APPENDIX A

SAMPLING SCHEDULES FOR SIMULTANEOUS STACK TESTS



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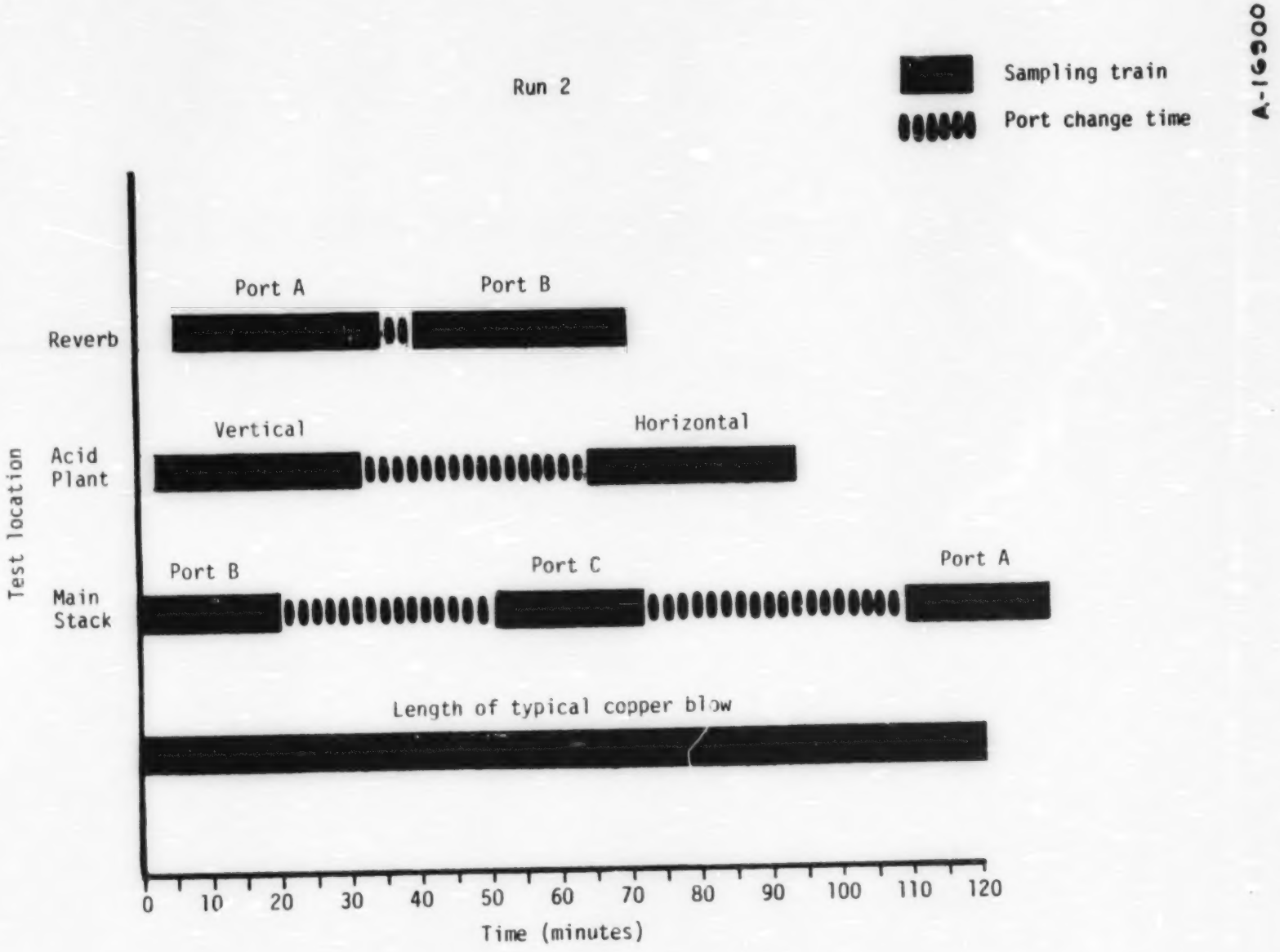
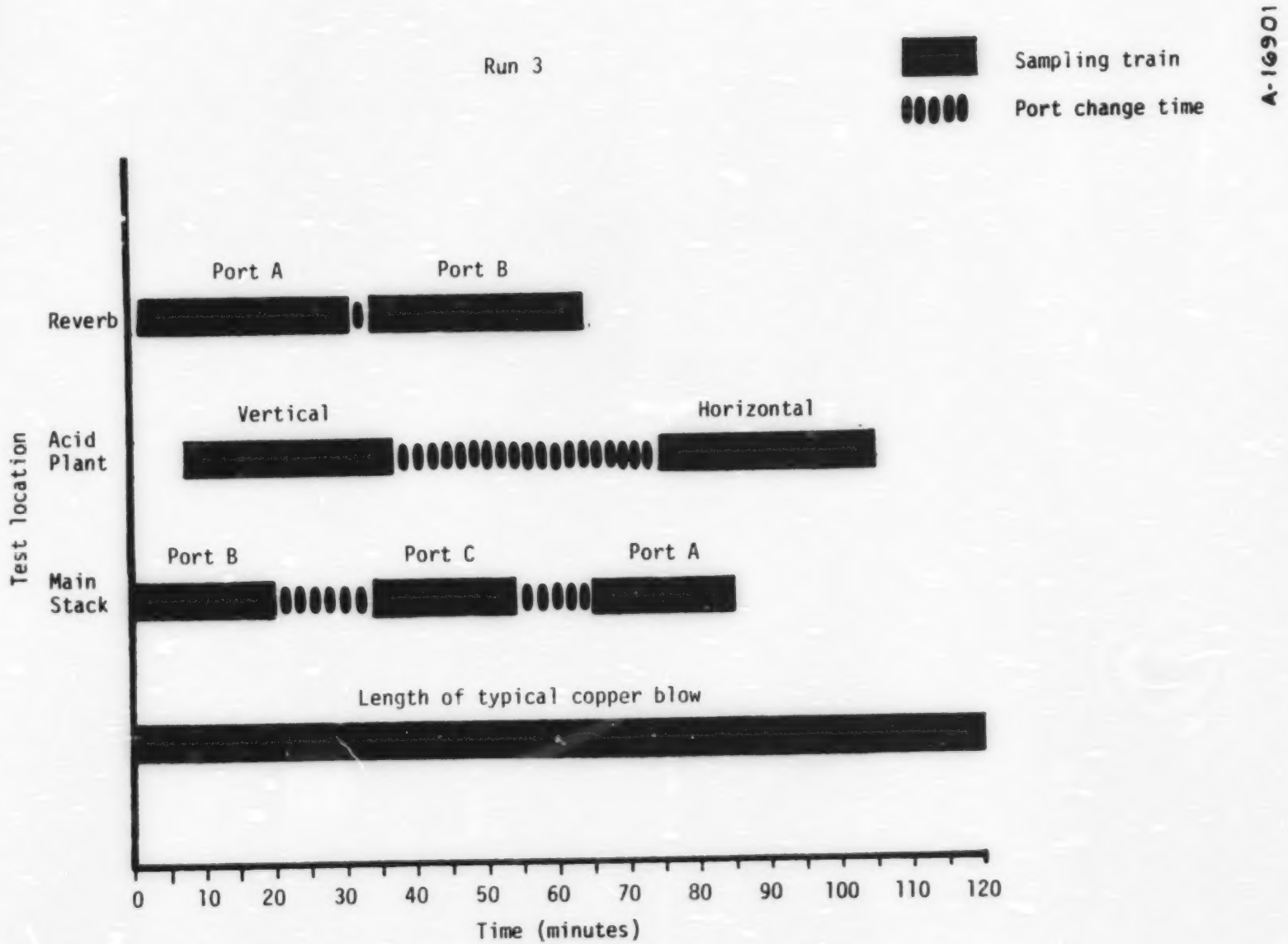
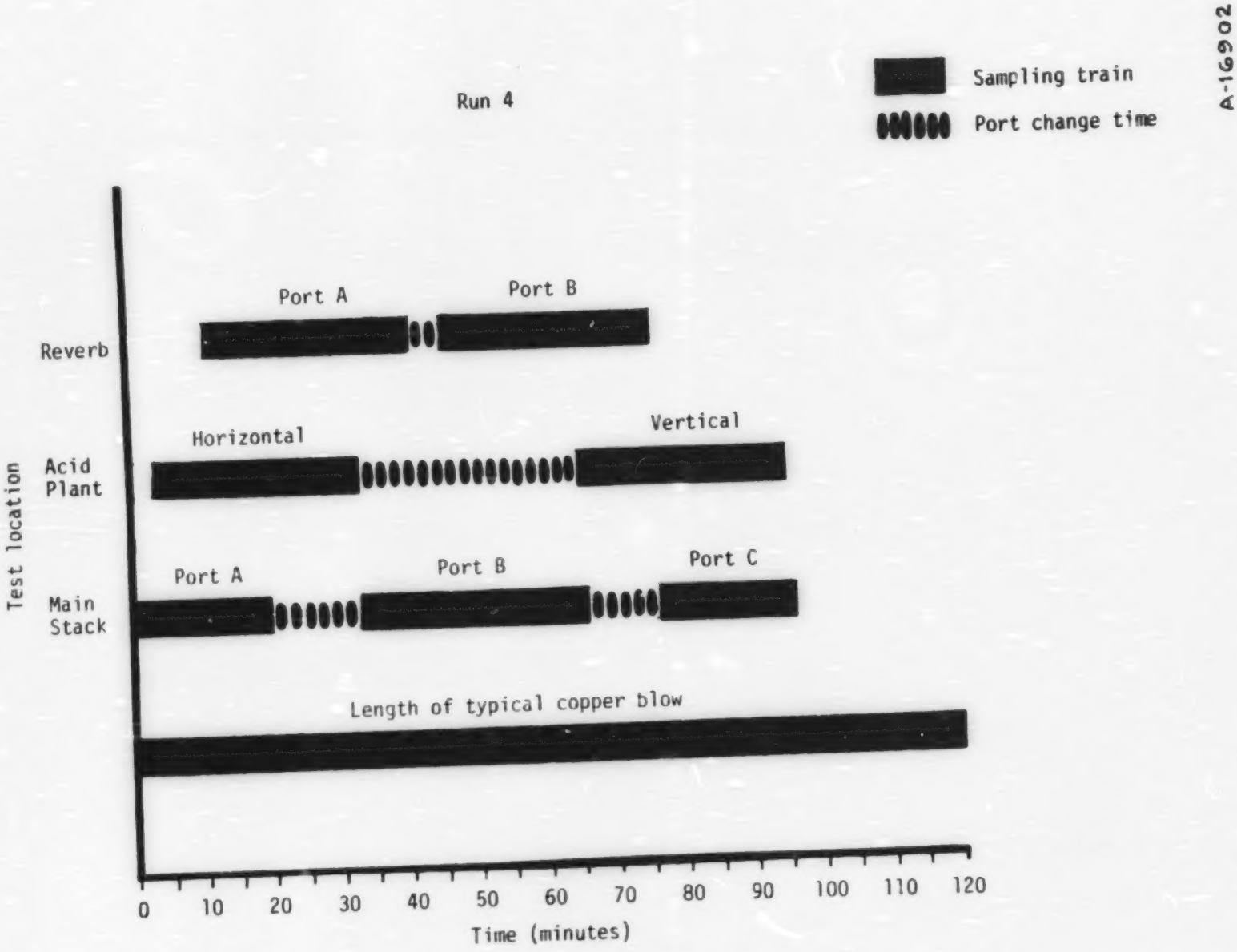
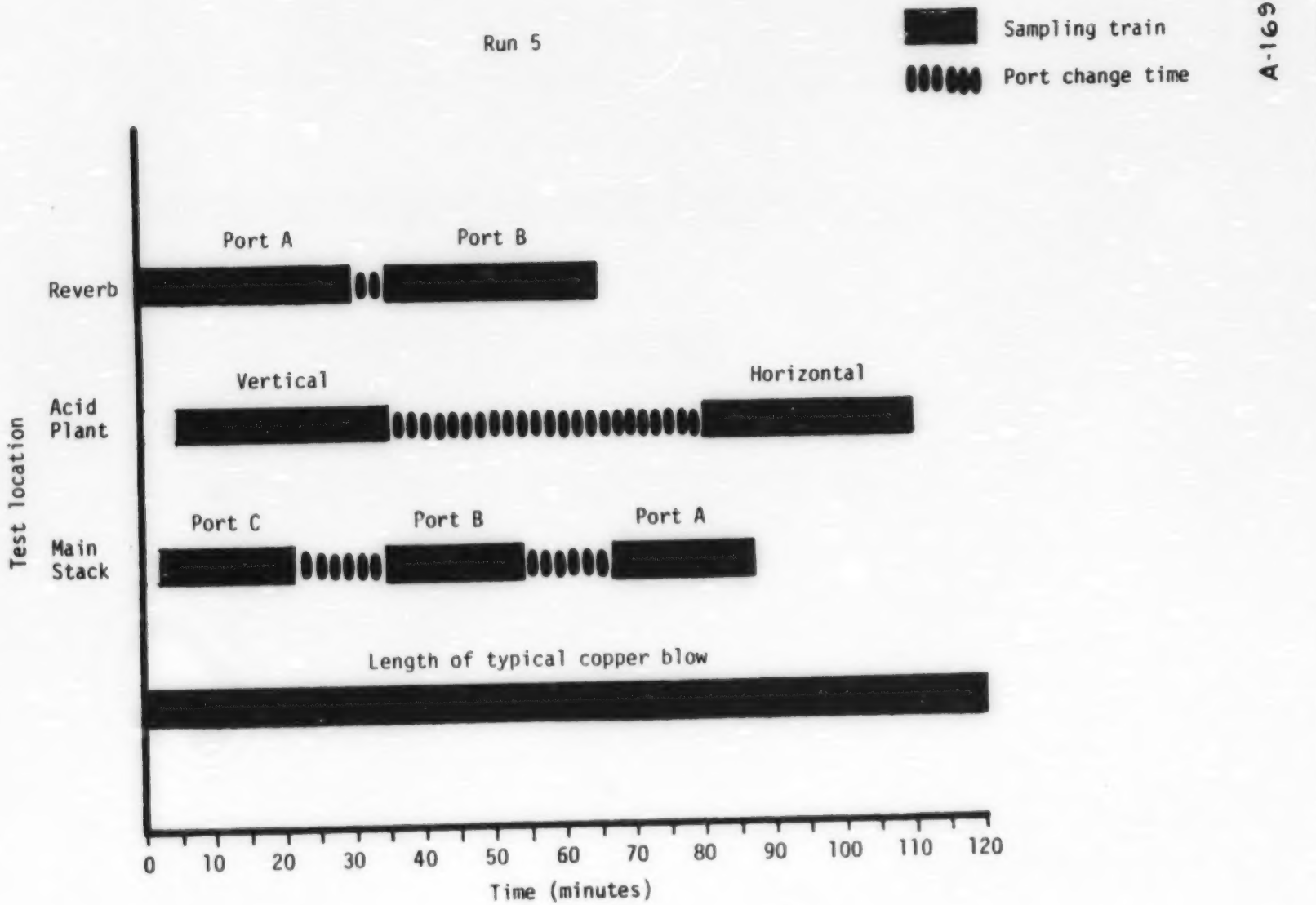
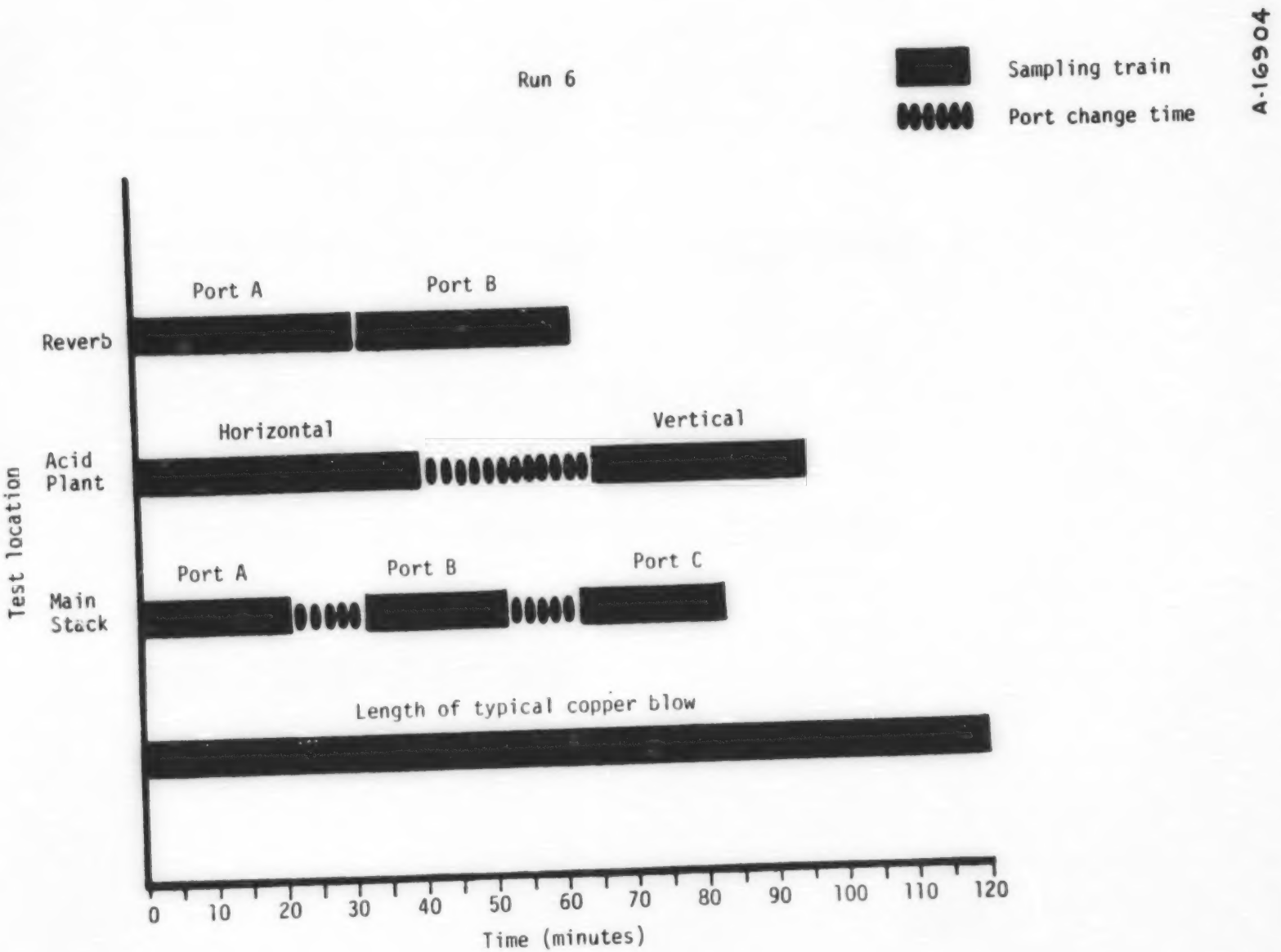
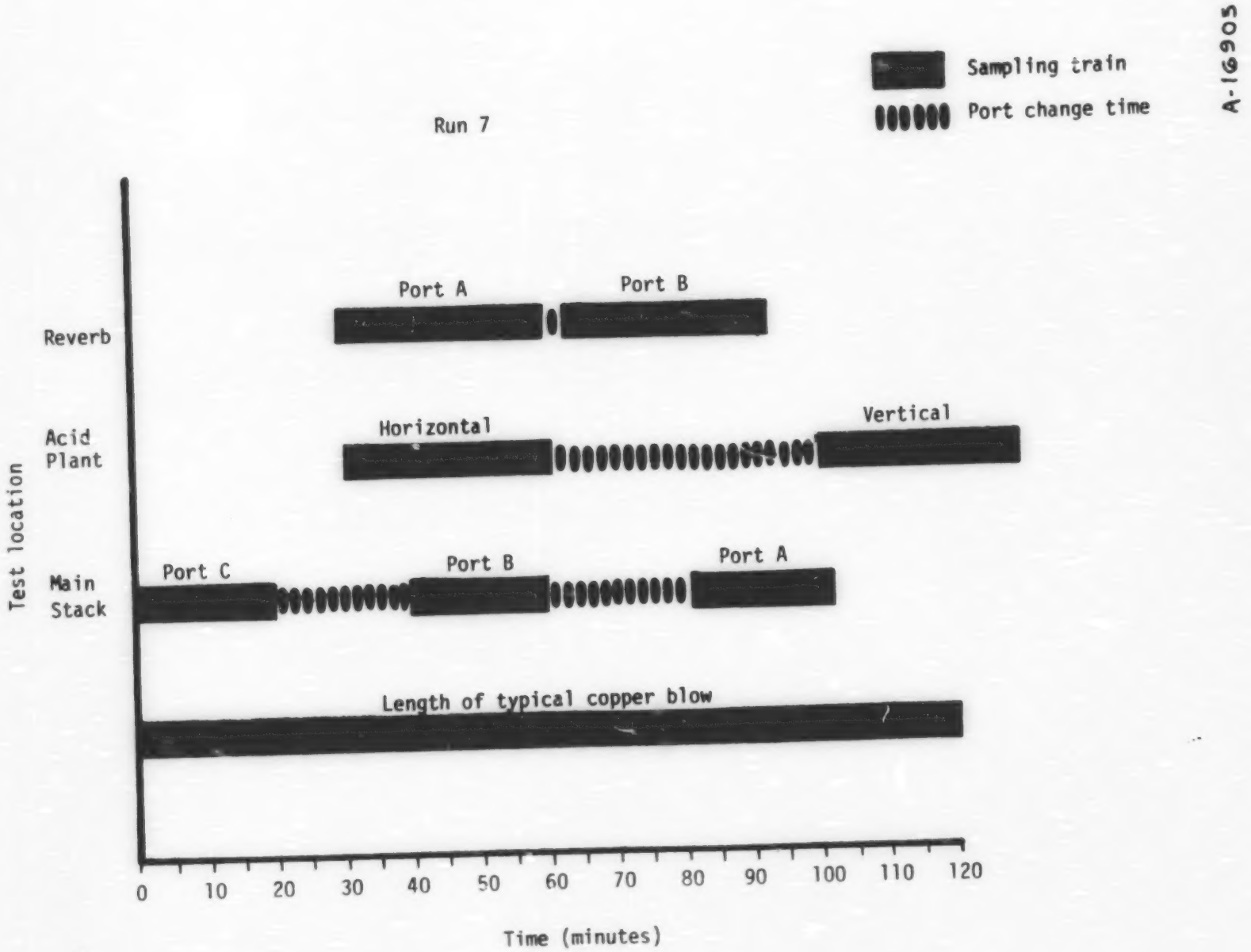

Run 2
Sampling train
Port change time
A-16900
Port A
Port B
Reverb
Vertical
Horizontal
Acid Plant
Port B
Port C
Port A
Main Stack
Test location
Length of typical copper blow
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (minutes)

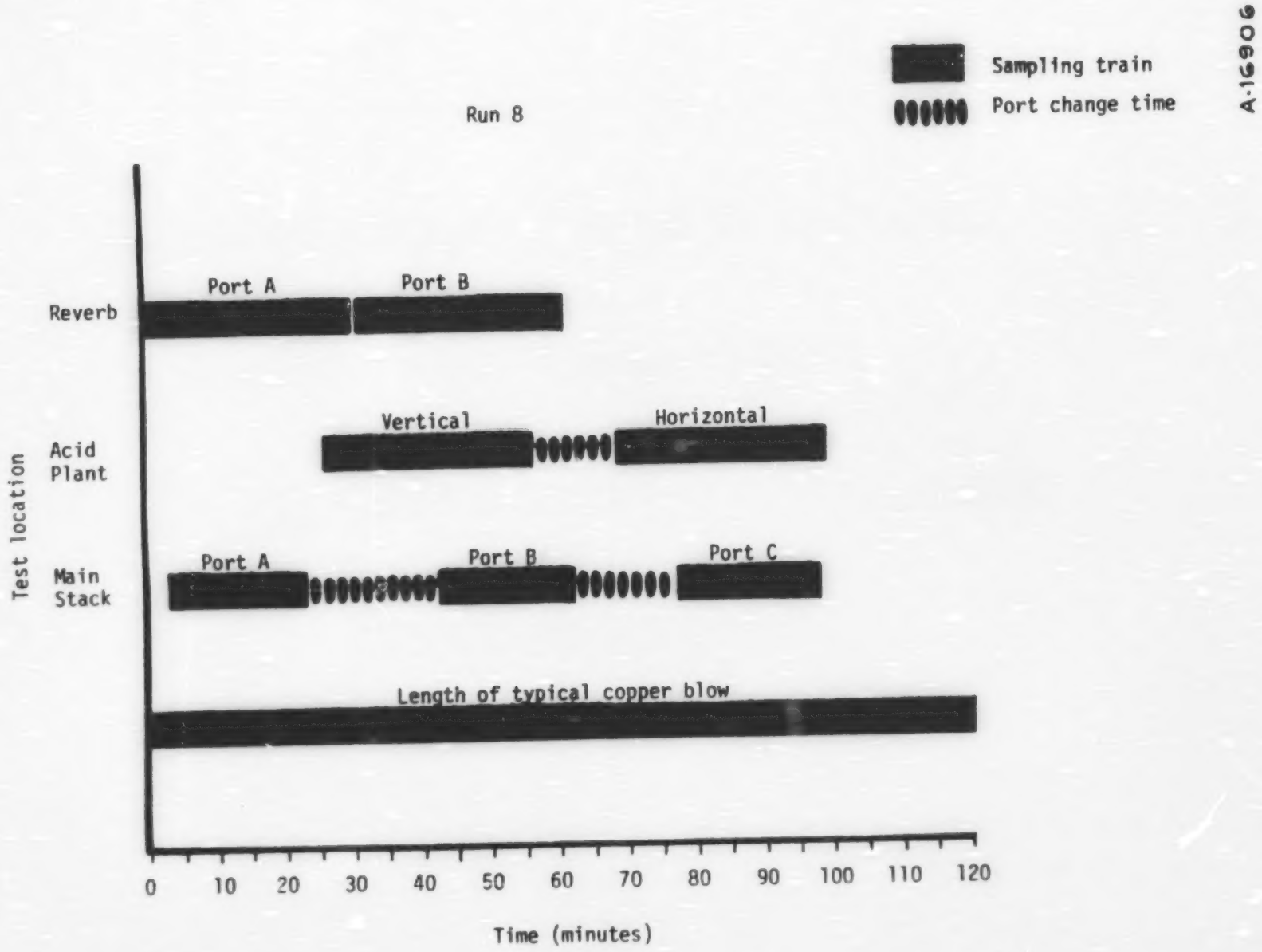

Run 3
Sampling train
Port change time
A-16901
Port A
Port B
Reverb
Vertical
Horizontal
Acid Plant
Test location
Port B
Port C
Port A
Main Stack
Length of typical copper blow
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (minutes)

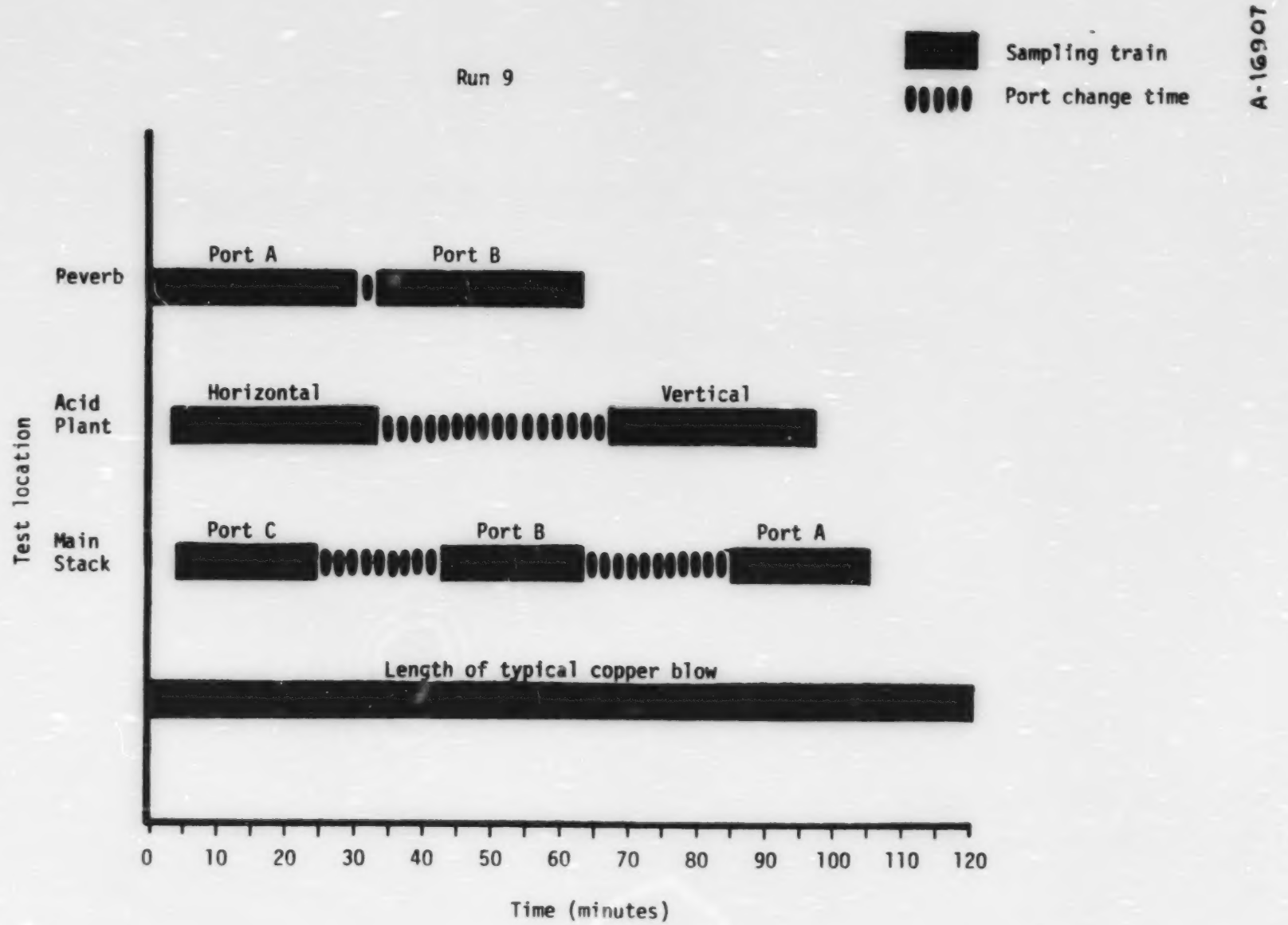

Run 4
Sampling train
Port change time
A-16902
Test location
Reverb
Port A
Port B
Acid Plant
Horizontal
Vertical
Main Stack
Port A
Port B
Port C
Length of typical copper blow
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (minutes)

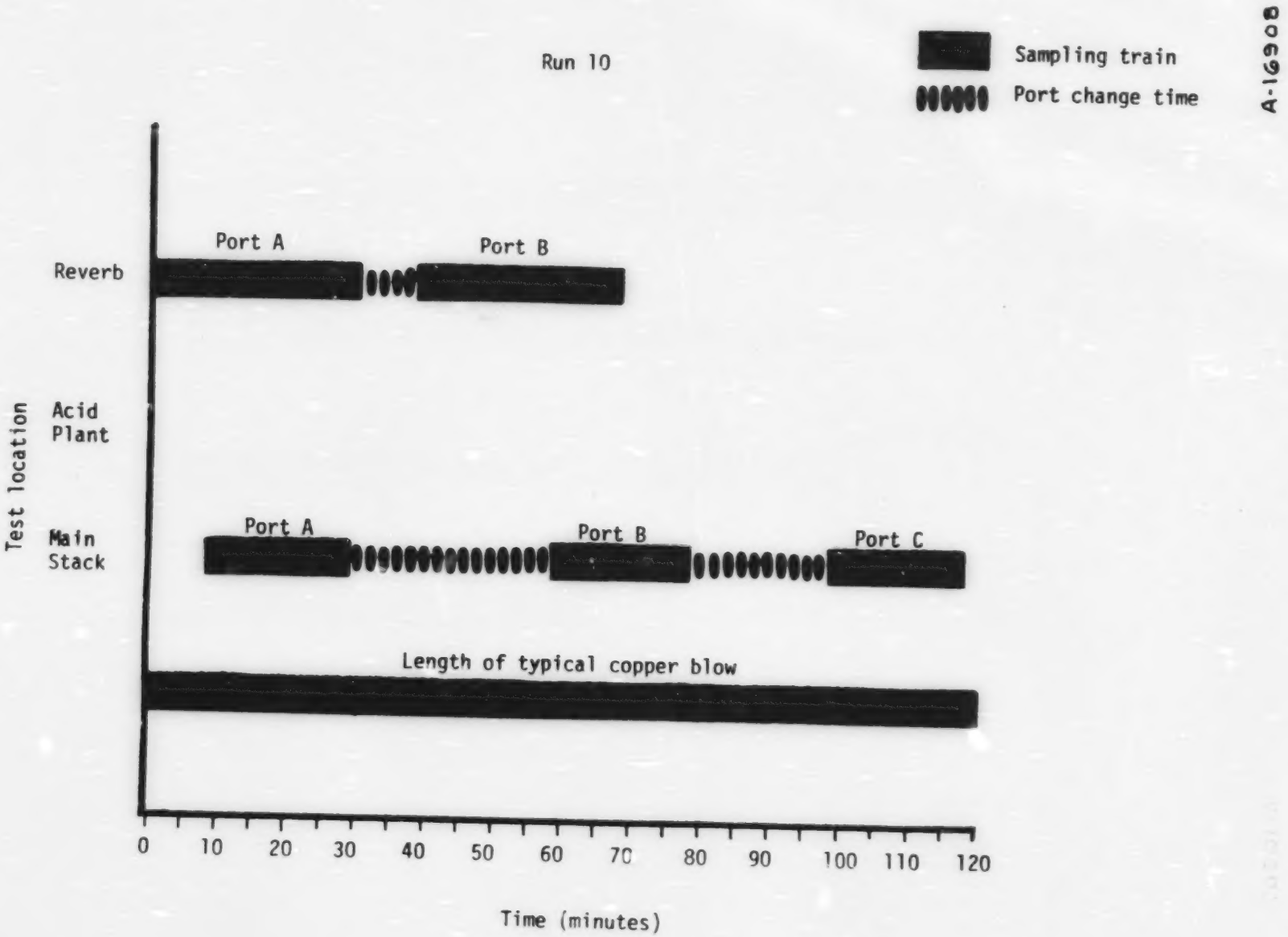

Run 5
Sampling train
Port change time
A-16903
Port A
Port B
Reverb
Vertical
Horizontal
Acid Plant
Port C
Port B
Port A
Main Stack
Test location
Length of typical copper blow
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (minutes)

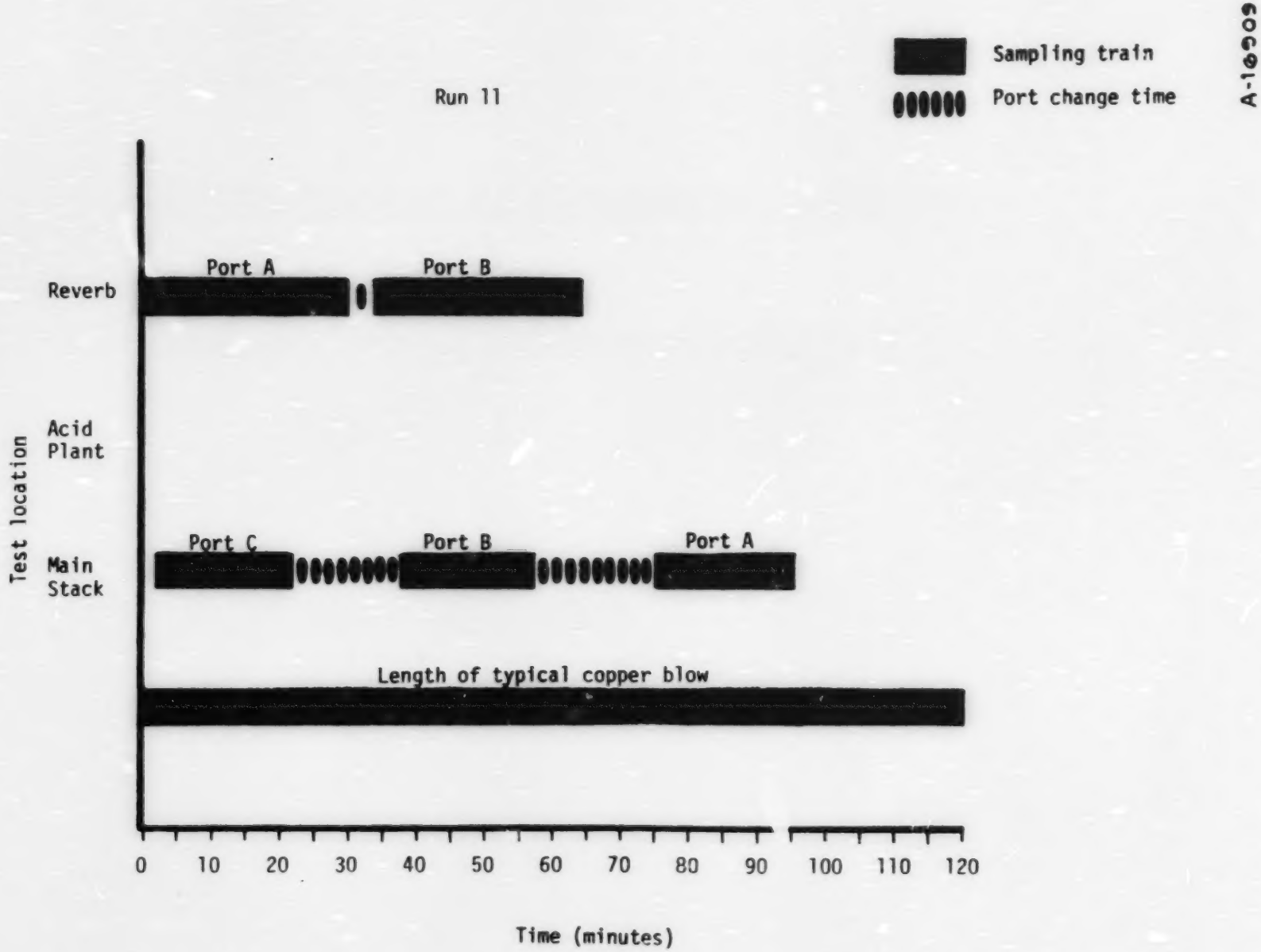

Run 6
Sampling train
Port change time
A-16904
Port A
Port B
Reverb
Horizontal
Vertical
Acid Plant
Test location
Port A
Port B
Port C
Main Stack
Length of typical copper blow
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (minutes)

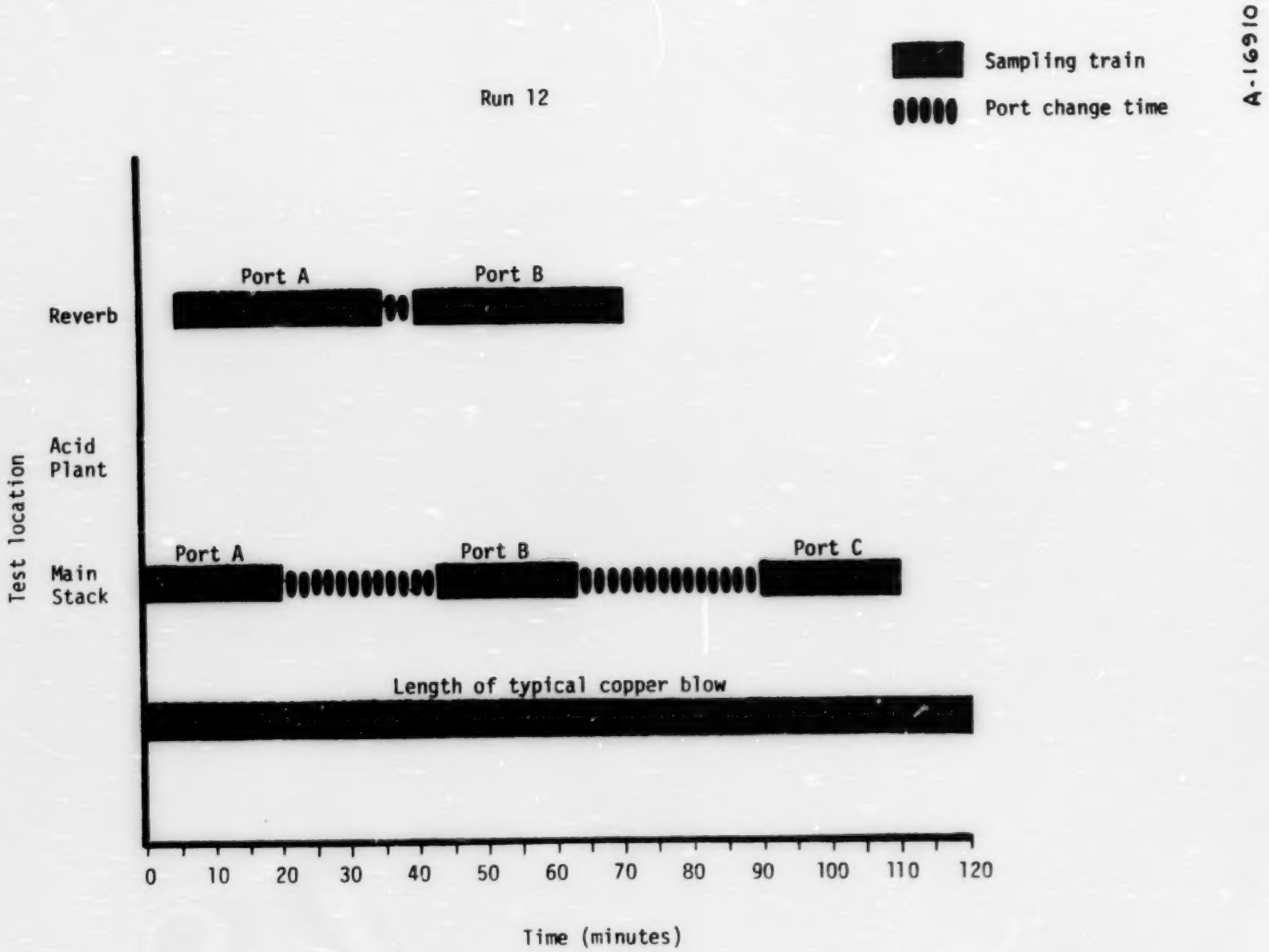

Run 7
Sampling train
Port change time
A-16905
Test location
Reverb
Acid Plant
Main Stack
Port A
Port B
Horizontal
Vertical
Port C
Port B
Port A
Length of typical copper blow
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (minutes)


Run 8
Sampling train
Port change time
A-16906
Reverb
Port A
Port B
Acid Plant
Vertical
Horizontal
Main Stack
Port A
Port B
Port C
Length of typical copper blow
Test location
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (minutes)


Run 9
Sampling train
Port change time
A-16907
Test location
Peverb
Port A
Port B
Acid Plant
Horizontal
Vertical
Main Stack
Port C
Port B
Port A
Length of typical copper blow
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (minutes)


Run 10
Sampling train
Port change time
A-16908
Test location
Reverb
Port A
Port B
Acid Plant
Main Stack
Port A
Port B
Port C
Length of typical copper blow
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (minutes)


Sampling train
Port change time
A-16909
Run 11
Reverb
Port A
Port B
Acid Plant
Main Stack
Port C
Port B
Port A
Test location
Length of typical copper blow
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (minutes)


Run 12
Sampling train
Port change time
A-16910
Test location
Reverb
Acid Plant
Main Stack
Port A
Port B
Port A
Port B
Port C
Length of typical copper blow
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (minutes)

APPENDIX B

WEIGHT VERSUS TIME CURVE FOR GLASS FIBER FILTER

As indicated in Section 7 of Volume I of this report, the particulate matter caught on the glass fiber filters at all three test locations (Acid Plant, Reverb. Main Stack) was very hygroscopic in nature and could not be weighed directly. Instead a weight versus time curve was prepared for each filter. Basically, two curves were prepared for each filter – one curve illustrating the change in weight during the initial few minutes of exposure to ambient conditions inside the analytical balance's weighing chamber, and a second curve illustrating the long term changes in weight. Figures B-1 and B-2 illustrate two typical curves.

Examining the data in Figure B-1, it can be seen that as soon as the filter is exposed to the ambient air, its weight starts to change very rapidly due to adsorption of water vapor onto the surface of the hygroscopic particulate matter. It took ~10 to 20 seconds for the analyst to adjust the dials on the balance to get the first weight reading. Several more readings were taken over the next few minutes to accurately plot the shape of the curve so that it could be extrapolated to zero time which presumably is the true weight of the filter and particulate without the presence of any uncombined water. Several more readings were then taken over an extended period of time to determine the equilibrium weight which the filter eventually reached. From Figure B-2, it can be seen that it took ~20 to 24 hours for the filter weight to level off at an equilibrium value.

It is important to note that the definition of particulate matter does not include uncombined water and hence, the extrapolated weight or true weight was used in the emission rate calculations.

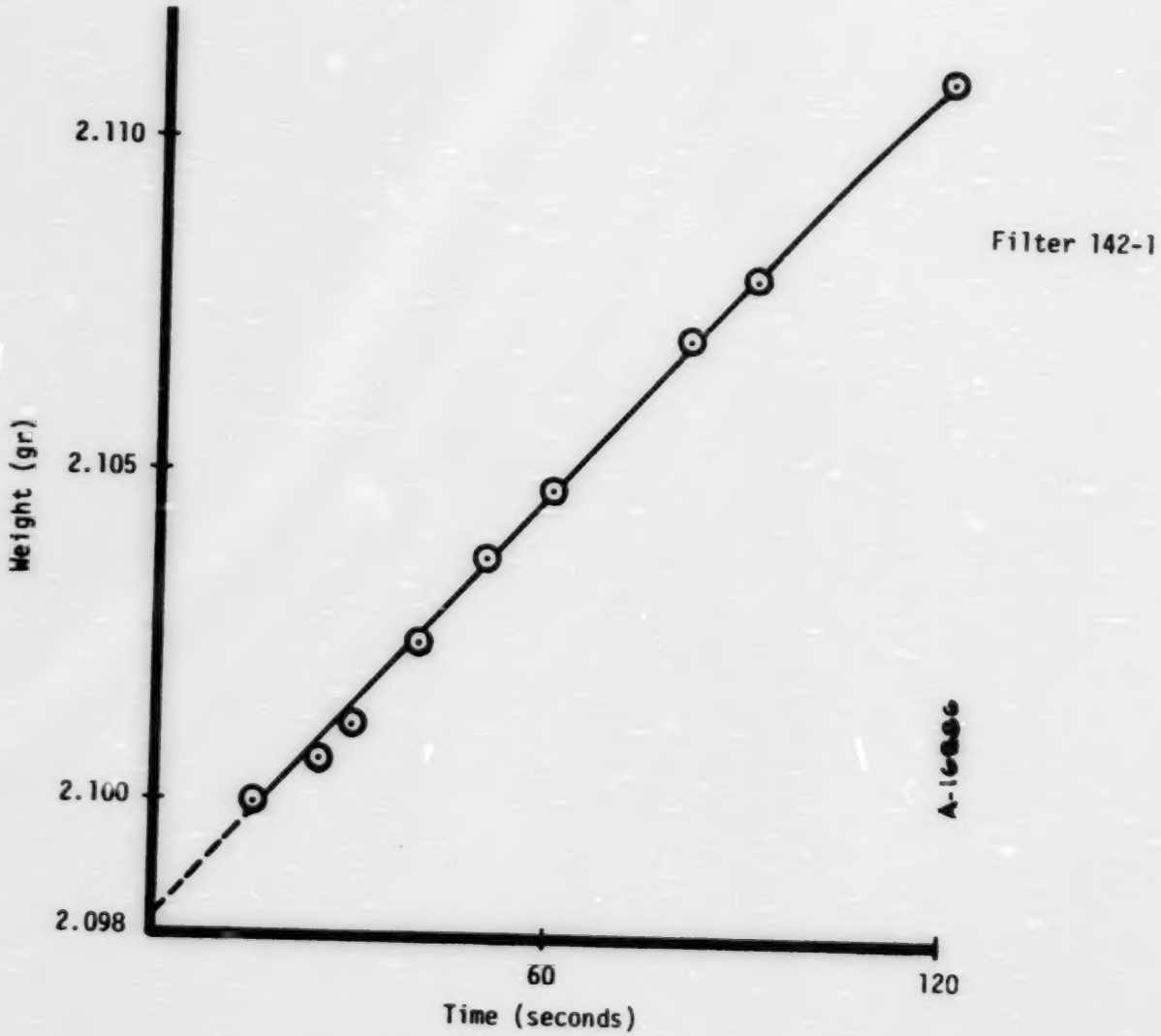


Figure B-1. Short term weight versus time curve.

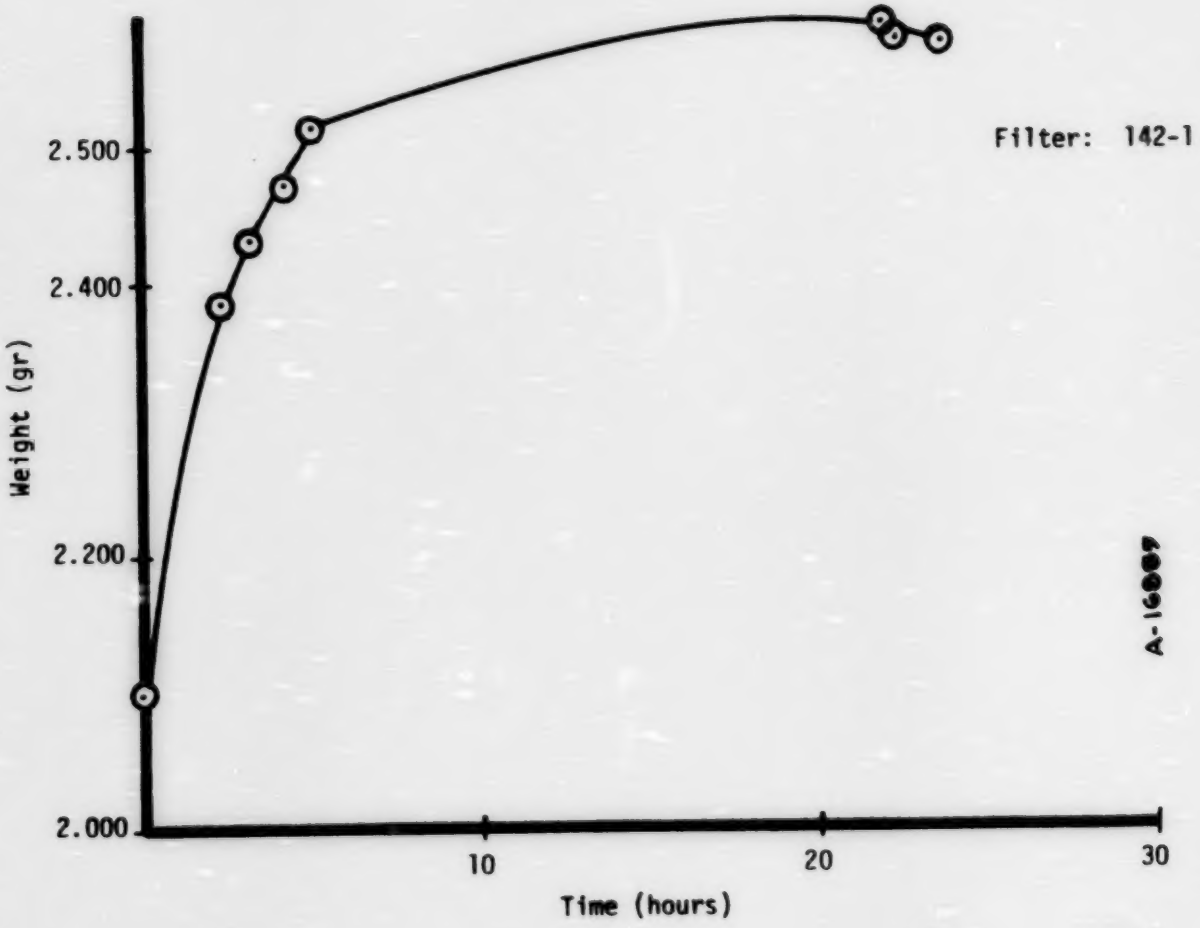


Figure B-2. Long term weight versus time curve.

APPENDIX C

SAMPLE CALCULATION FOR STATISTICAL ANALYSIS

The mathematical formulas used to calculate the mean, the standard deviation and the 90 percent confidence limits for the particulate, SO_3/H_2SO_4 and SO_2 emission data were taken from a series of reports prepared by the Research Triangle Institute under contract to EPA (EPA Report 600/4-74-005 a to j entitled "Guidelines for Development of a Quality Assurance Program"). An example of each statistical calculation is given below based on data obtained from the Acid Plant tests.

1. Mean Particulate Emission Rate

$$\overline{ER} = \frac{ER_1 + ER_2 + ER_3 + ER_5 + ER_6 + ER_7 + ER_8 + ER_9}{9}$$

where $\overline{ER}$ = mean particulate emission rate, lb/hr

ER_1 = measured particulate emission rate for Test #1, lb/hr

ER_2 = measured particulate emission rate for Test #2, lb/hr

9 = number of tests conducted at the Acid Plant

$$\overline{ER} = \frac{6.5 + 5.4 + 6.4 + 9.2 + 6.0 + 5.5 + 6.2 + 6.4 + 8.0}{9}$$

$$= \frac{59.6}{9}$$

$$= 6.6 \text{ lb/hr}$$

2. Standard Deviation of Particulate Emission Rate

$$s(ER) = \left\{\frac{(ER_1 - \overline{ER})^2 + (ER_2 - \overline{ER})^2 + \cdots + (ER_9 - \overline{ER})^2}{8}\right\}^{1/2}$$

where $s(ER)$ = standard deviation for the nine tests at the Acid Plant, lb/hr

ER_1 = measured particulate emission rate for Test #1, lb/hr

$\overline{ER}$ = mean particulate emission rate for nine tests at the Acid Plant, lb/hr

8 = number of tests at the Acid Plant minus one (equals number of degrees of freedom)

$$s(ER) = \left\{\frac{(6.5 - 6.6)^2 + (5.4 - 6.6)^2 + \cdots + (8.0 - 6.6)^2}{8}\right\}^{1/2}$$

$$= \left\{\frac{(0.1)^2 + (1.2)^2 + \cdots + (1.4)^2}{8}\right\}^{1/2}$$

$$= 1.2 \text{ lb/hr}$$

3. Ninety Percent Confidence Limits of Particulate Emission Rate

The mean particulate emission rate and the standard deviation of the data are used to calculate confidence limits for the emission data according to:

$$\overline{ER} \pm \frac{1.86\ s(ER)}{\sqrt{9}}$$

where $\overline{ER}$ = mean particulate emission rate for nine tests at the Acid Plant, lb/hr

1.86 = 95th percentile of the Student t-distribution with 8 degrees of freedom which yields a 90 percent confidence interval

s(ER) = standard deviation for the nine tests at the Acid Plant, lb/hr

9 = number of tests conducted at the Acid Plant

$$6.6 \pm \frac{1.86(1.2)}{\sqrt{9}}$$

$$= 6.6 \pm 0.7$$

therefore $5.8 \text{ lb/hr} \leq \overline{ER} \leq 7.4 \text{ lb/hr}$

These statistical calculations have been made after examining the raw emission data, after making the appropriate corrections, or after rejecting the data entirely.

APPENDIX D

INDIVIDUAL PROCESS WEIGHT CALCULATIONS

INDIVIDUAL PROCESS WEIGHT CALCULATIONS

Date	Shift	Converter Blowing Copper During Test	Start Time of Copper Blow	End Time of Copper Blow	Converter Copper Output at End of Copper Blow (tons)	Converter Mass Flow for 24-Hour Period Encompassing Test						Maximum Allowable Emission Rate From Converter (lb/hr)
						Matte Input (tons)	Flux Input (tons)	Chips and Dust Input (tons)	Total Input to Converter (tons)	Total Matte and Copper Blow Time (hrs:min)	Converter Process Weight Rate (tons/hr)	
7/20	B	1	16:10	18:25	45	252	43.5	20	315.5	6:55	45.61	31.90
7/21	A	1	7:50	10:55	55	220.5	42	44	306.5	11:45	26.09	27.42
7/21	B	3	17:20	19:00	35	252	47.25	28	327.3	6:25	51.01	32.47
7/22	A	1	9:55	12:10	35	362.25	55.5	31.2	448.95	11:45	38.21	31.01
7/23	A	1	9:05	11:40	52	236.25	53.25	50	339.5	10.55	31.10	30.00
7/26	A	1	8:50	11:20	52	189	30.75	36	255.75	10:25	24.55	26.12
7/26	B	3	14:50	16:40	35	157.5	33.75	44.8	236.05	8:15	28.61	28.72
7/27	A	3	8:35	10:35	35	283.5	46.5	46	376.0	10:55	34.44	30.49
7/28	A	1	11:10	14:40	65	252	48	34	334.0	9:30	35.16	30.60
7/28	B	3	19:15	21:30	55	283.5	33.75	40	357.55	10:10	35.14	30.59
7/29	A	3	10:15	12:15	50	456.75	36	78	570.75	15:15	37.43	30.90
7/29	B	3	15:55	18:00	40	456.75	36	78	570.75	15:15	37.43	30.90
7/30	A	3	11:10	13:40	50	409.5	45	55.2	509.70	15:10	33.61	30.38

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INDIVIDUAL PROCESS WEIGHT CALCULATIONS (Concluded)

Reverberatory Furnace Mass Flow For One Shift Period Encompassing Test										Minimum Allowable Emission Rate From Reverb	Total Maximum Allowable Emission Rate (lb/hr)
Matte Output From Reverb (tons)	Natural Gas Input ft^3/hr (thousands)	Air Input ft^3/hr (thousands)	Concentrate Input (tons)	Converter Slag Input (tons)	Precipitate Input (tons)	Lime Input (tons)	Dust Input (tons)	Total Solid Input to Reverb (tons)	Reverb Process Weight (tons/hr)		
126	173	1,820	177	123	8	13	6	327	40.88	31.34	63.24
189	172	1,820	176	116	8	14	7	321	40.13	31.25	58.37
63	172	1,820	160	145	8	13	6	332	41.50	31.42	63.89
126	173	1,820	191	124	8	15	7	345	43.13	31.61	62.62
158	173	1,820	159	174	8	13	8	362	45.25	31.86	61.86
126	176	1,820	175	116	6	15	8	320	40.0	31.23	57.35
126	176	1,820	165	87	5	12	6	275	34.38	30.49	59.21
126	175	1,820	142	131	2	11	8	294	36.75	30.81	61.30
126	173	1,820	171	93	4	14	6	288	36.0	30.71	61.31
189	173	1,820	159	160	7	17	5	348	43.50	31.66	62.25
158	174	1,820	154	160	2	14	8	338	42.25	31.51	62.41
173	174	1,820	166	116	4	16	6	308	38.50	31.04	61.94
189	167	1,820	180	131	0	15	9	343	42.88	31.58	61.96

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APPENDIX E

INDIVIDUAL FILTER, PARTICULATE AND RESIDUE WEIGHT DATA

INDIVIDUAL FILTER, PARTICULATE AND RESIDUE WEIGHT DATA — FIRST READING

T-264

Location	Test	Filter Numbers	Tare Weight (mg)	Dust & Filter Weight (mg)	Dust Weight (mg)	Residue Weight (mg)	M (Total Weight) (mg)
Main	1	142-5	999.21	1,429.00	429.79	117.13	546.92
	2	142-12	1,003.93	1,642.80	638.87	170.73	809.92
	3	142-33	1,017.23	1,834.50	817.27	117.64	934.91
	4	142-11	1,013.02	1,618.20	605.18	236.39	841.57
	5	142-35	1,014.74	1,509.00	494.26	181.03	675.29
	6	142-9	1,003.40	1,542.00	538.60	194.73	733.33
	7	142-26	1,019.07	1,442.50	423.43	103.69	527.12
	8	142-24	1,017.43	1,113.00	95.57	192.89	288.46
	9	142-8	1,003.38	1,984.00	980.62	324.59	1,305.21
	10	142-40	1,014.77	1,046.00	31.23	63.08	734.06
		47-2	129.40	300.00	170.60		
		47-3	128.45	383.00	254.55		
		47-7	125.49	340.50	214.51		
	11	142-38	1,014.80	1,032.00	17.20	131.48	733.97
		47-22	126.89	322.00	195.11		
		47-23	126.75	336.51	209.76		
		11-A	127.20	273.00	145.80		
	12	142-25	1,010.51	1,035.00	24.49	67.21	825.07
		#20	127.48	379.70	252.22		
		#21	125.49	337.70	212.21		
		#23	128.93	397.87	268.94		
Reverb ESP	1	142-1	1,006.12	2,100.00	1,093.88	635.11	1,728.99
	2	142-32	1,016.62	1,946.80	930.18	862.49	1,792.67
	3	142-14	1,007.84	1,875.50	867.66	842.76	1,710.42
	4	142-44	1,021.13	2,105.60	1,084.47	588.00	1,672.47
	5	142-46	1,016.38	1,868.20	851.82	295.74	1,147.56
	6	142-2	1,010.10	1,927.00	916.90	969.96	1,886.86
	8	142-39	1,018.80	1,812.00	793.20	1,001.19	1,794.39
	9	142-17	1,009.78	1,892.00	882.22	857.24	1,739.46
	10	142-7	1,007.53	2,088.00	1,080.47	1,058.60	2,222.25
		47-20	129.53	191.00	61.47		
		47-21	129.79	151.50	21.71		
	11	142-22	1,019.04	2,163.00	1,143.96	1,052.98	2,292.48
		47-4	128.66	205.20	76.54		
		47-5	126.10	145.10	19.00		
	12	142-23	1,016.89	2,335.00	1,318.11	1,080.57	2,427.52
		#19	125.15	197.76	76.61		
		#24	121.16	150.00	28.84		
Acid Plant	1	142-4	1,014.52	1,051.00	36.48	98.55	135.03
	2	142-6	1,003.88	1,034.50	30.62	37.44	68.06
	3	142-48	1,012.34	1,046.00	33.66	9.16	42.82
	4	142-31	1,015.84	1,079.80	63.96	49.81	113.77
	5	142-20	1,014.62	1,040.00	25.38	59.19	84.57
	6	142-47	1,021.26	1,051.00	29.74	43.14	72.88
	7	142-15	1,013.75	1,042.00	28.25	244.80	273.05
	8	142-10	1,020.07	1,047.00	26.93	115.45	142.38
	9	142-3	1,011.46	1,063.00	51.54	45.58	97.12

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INDIVIDUAL FILTER, PARTICULATE AND RESIDUE WEIGHT DATA – EQUILIBRIUM

T-265

Location	Test	Filter Numbers	Tare Weight (mg)	Dust & Filter Weight (mg)	Dust Weight (mg)	Residue Weight (mg)	M (Total Weight) (mg)
Main	1	142-5	999.21	1,667.65	668.44	117.13	785.57
	2	142-12	1,003.93	1,951.30	947.37	170.73	1,118.10
	3	142-33	1,017.23	2,245.05	1,227.82	117.64	1,345.46
	4	142-11	1,013.02	1,929.08	916.06	236.39	1,152.45
	5	142-35	1,014.74	1,780.85	766.11	181.03	947.14
	6	142-9	1,003.40	1,830.20	826.80	194.73	1,021.53
	7	142-26	1,019.07	1,729.75	710.68	103.69	814.37
	8	142-24	1,017.43	1,162.50	145.07	192.89	337.96
	9	142-8	1,003.38	2,619.00	1,615.62	324.59	1,940.21
	10	142-40	1,014.77	1,053.50	38.73	63.08	1,106.12
		47-2	129.40	383.95	254.55		
		47-3	128.45	543.70	415.25		
		47-7	125.49	460.00	334.51		
	11	142-38	1,014.80	1,034.50	19.70	131.48	966.67
		47-22	126.89	401.85	274.96		
		47-23	126.75	444.50	317.75		
		11-A	127.20	349.98	222.78		
	12	142-25	1,010.51	1,050.25	39.74	67.21	1,194.70
		#20	127.48	492.31	364.83		
		#21	125.49	469.50	344.01		
		#23	128.93	507.84	378.91		
Reverb ESP	1	142-1	1,006.12	2,578.10	1,571.98	635.11	2,207.09
	2	142-32	1,016.62	2,339.00	1,322.38	862.49	2,184.87
	3	142-14	1,007.84	2,305.13	1,297.29	842.76	2,140.05
	4	142-44	1,021.13	2,685.00	1,663.87	588.00	2,251.87
	5	142-46	1,016.38	2,474.70	1,458.32	295.74	1,754.06
	6	142-2	1,010.10	2,506.10	1,496.00	969.96	2,465.96
	8	142-39	1,018.80	2,126.40	1,107.60	1,001.19	2,108.79
	9	142-17	1,009.78	2,466.50	1,456.72	857.24	2,313.96
	10	142-7	1,007.53	2,694.30	1,686.77	1,058.60	2,867.23
		47-20	129.53	223.68	94.15		
		47-21	129.79	157.50	27.71		
	11	142-22	1,019.04	2,734.00	1,714.96	1,052.98	2,792.74
		47-4	128.66	253.00	124.34		
		47-5	126.10	150.90	24.80		
	12	142-23	1,016.89	3,065.30	2,048.41	1,080.57	2,941.92
		#19	125.15	234.25	109.10		
		#24	121.16	158.45	37.29		
Acid Plant	1	142-4	1,014.52	1,058.13	43.61	98.55	142.16
	2	142-6	1,003.88	1,051.90	48.02	37.44	85.46
	3	142-48	1,012.34	1,067.15	54.81	9.16	63.97
	4	142-31	1,015.84	1,121.50	105.66	49.81	155.47
	5	142-20	1,014.62	1,052.40	37.78	59.19	96.97
	6	142-47	1,021.26	1,068.30	47.04	43.14	90.18
	7	142-15	1,013.75	1,060.45	46.70	244.80	291.50
	8	142-10	1,020.07	1,050.55	30.48	115.45	145.93
	9	142-3	1,011.46	1,095.62	84.16	45.58	129.74

INDIVIDUAL FILTER, PARTICULATE AND RESIDUE WEIGHT DATA – AT 0 SEC.

T-266

Location	Test	Filter Numbers	Tare Weight (mg)	Dust & Filter Weight (mg)	Dust Weight (mg)	Residue Weight (mg)	M (Total Weight) (mg)
Main	1	142-5	999.21	1,424.80	425.59	117.13	542.72
	2	142-12	1,003.93	1,640.70	636.77	170.73	807.50
	3	142-33	1,017.23	1,832.50	815.27	117.64	932.91
	4	142-11	1,013.02	1,614.75	601.73	236.39	838.12
	5	142-35	1,014.74	1,505.20	490.46	181.03	671.49
	6	142-9	1,003.40	1,539.00	535.60	194.73	730.33
	7	142-26	1,019.07	1,435.30	416.23	103.69	519.92
	8	142-24	1,017.43	1,110.80	93.37	192.89	286.26
	9	142-8	1,003.38	1,981.20	977.82	324.59	1,302.41
	10	142-40	1,014.77	1,045.15	30.38	63.08	727.78
		47-2	129.40	298.00	168.60		
		47-3	128.45	380.06	251.61		
		47-7	125.49	339.60	214.92		
	11	142-38	1,014.80	1,032.00	17.20	131.48	697.06
		47-22	126.89	323.50	196.61		
		47-23	126.75	335.60	208.85		
		11-A	127.20	270.12	142.92		
	12	142-25	1,010.51	1,031.95	21.44	67.21	816.88
		#20	127.48	377.05	249.57		
		#21	125.49	337.00	211.51		
		#23	128.93	396.08	267.15		
Reverb ESP	1	142-1	1,006.12	2,098.22	1,092.10	635.11	1,727.21
	2	142-32	1,016.62	1,945.39	928.77	862.49	1,791.26
	3	142-14	1,007.84	1,873.40	865.56	842.76	1,708.32
	4	142-44	1,021.13	2,103.10	1,081.97	588.00	1,669.97
	5	142-46	1,016.38	1,866.50	850.12	295.74	1,145.86
	6	142-2	1,010.10	1,922.00	911.90	969.96	1,881.86
	8	142-39	1,018.80	1,810.00	791.20	1,001.19	1,792.39
	9	142-17	1,009.78	1,770.00	760.22	857.24	1,617.46
	10	142-7	1,007.53	2,085.20	1,077.67		
		47-20	129.53	189.75	60.22		
		47-21	129.79	151.56	21.77	1,058.60	2,218.26
	11	142-22	1,019.04	2,155.30	1,136.26	1,052.98	2,282.87
		47-4	128.66	203.50	74.84		
		47-5	126.10	144.89	18.79		
	12	142-23	1,016.89	2,231.75	1,214.86	1,080.57	2,390.66
		#19	125.15	191.94	66.79		
		#24	121.16	149.60	28.44		
Acid Plant	1	142-4	1,014.52	1,047.70	33.18	98.55	131.73
	2	142-6	1,003.88	1,033.90	30.02	37.44	67.46
	3	142-48	1,012.34	1,044.20	31.86	9.16	41.02
	4	142-31	1,015.84	1,079.80	63.96	49.81	113.77
	5	142-20	1,014.62	1,038.87	24.25	59.19	83.44
	6	142-47	1,021.26	1,050.42	29.16	43.14	72.30
	7	142-15	1,013.75	1,040.72	26.97	244.80	271.77
	8	142-10	1,020.07	1,046.16	26.09	115.45	141.54
	9	142-3	1,011.46	1,061.65	50.19	45.58	95.77